Development of a Superconducting Helicon Thruster

Completed Technology Project (2011 - 2015)

Project Introduction

The Helicon Thruster is a potential in-space propulsion system that uses a cylindrical helicon plasma source to inductively develop non-thermal plasma. A key feature of the helicon source is an axial magnetic field that provides an efficient mechanism for forming the plasma. As a by-product, the diverging field lines at the exit plane of the cylinder cause the plasma to be accelerated to velocities in excess of 10,000 m/s, making it attractive as a thruster. The stronger the magnetic field, the higher the plasma density that can be supported and the higher the thrust that can be generated per unit area of the plasma. Providing a large magnetic field with the appropriate structure comes at the cost of high power consumption, which eliminates the benefit gained by the more efficient ionization. To address this issue, a novel approach based on the Meissner effect has been developed, whereby a cylinder of high temperature superconducting (HTS) material is used as a magnetic flux tube, confining and shaping the magnetic field of a permanent magnet. The resulting field can be up to several thousand Gauss, highly uniform along the length of the source and rapidly diverging at the exit. This rapid divergence of the magnetic field lines at the exit plane is anticipated to support prompt detachment of the exhaust beam, minimizing divergence of the plasma and further increasing performance. The key objective of the proposal is to develop and test a thruster constructed on this concept to determine its actual thrust capability, specific impulse and efficiency. The methods to be employed are both computational and experimental and the project will begin with the design and development of a segmented electromagnet with a variable field structure to analyze the effects of different field geometries on the plasma. Examples include 1) formation of an asymmetric magnetic mirror around the plasma and 2) shunting the field at the exit to vary the rate of divergence of the field lines. This magnet will be constructed and integrated into an existing helicon source. Its impact on the plasma will be measured using both optical diagnostics (line emission spectroscopy) to measure the plasma composition and a retarding potential analyzer to measure the plasma beam energy and beam divergence. Once a desirable field structure has been established, modeling will begin to determine how such a field can be generated with the permanent magnet/flux tube concept. This will be implemented along with the necessary thermal control to maintain the HTS material below its critical temperature. In the laboratory version, this will involve using liquid nitrogen, but in a flight version a cryocooler would most likely be used. The same test matrix will be conducted on the superconducting thruster, with the addition of direct thrust measurements using a thrust stand. The superconducting helicon thruster represents a significant technology innovation for NASA due to the ability to use water vapor as a propellant. Unlike most electric propulsion technologies, the inductively coupled plasma and electrodeless acceleration mechanism make the helicon thruster robust to using a variety of propellant types without electrode erosion. Water vapor as a propellant has been considered for some electrothermal systems, such as resistojets and even arcjets, however the limited specific impulse of the resistojet and the thermal

Project Image Development of a Superconducting Helicon Thruster

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

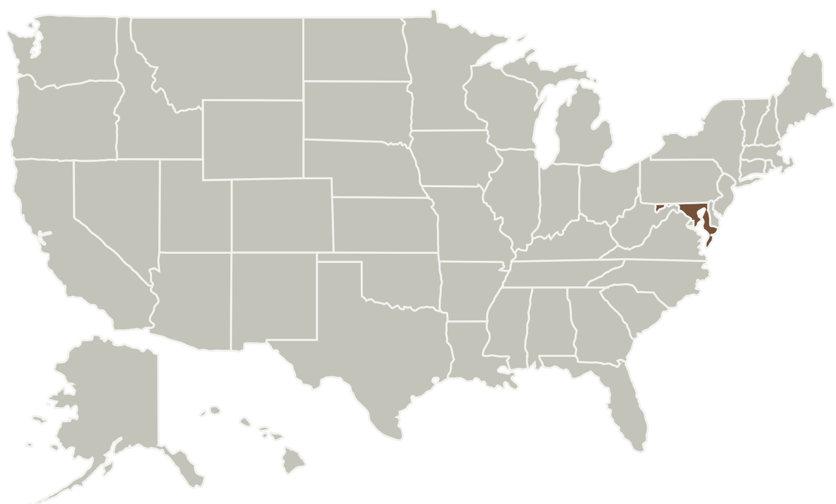
Space Technology Research Grants

plasma losses of the arcjet make them less desirable for high delta-V missions. The superconducting helicon thruster presents the possibility for developing higher specific impulse at much greater efficiency, comparable to that of existing state-of-the-are Hall thrusters. Using water vapor allows for in-situ resource utilization, since water is thought to be ubiquitous throughout the solar system.

Anticipated Benefits

The superconducting helicon thruster presents the possibility for developing higher specific impulse at much greater efficiency, comparable to that of existing state-of-the-art Hall thrusters. Using water vapor allows for in-situ resource utilization, since water is thought to be ubiquitous throughout the solar system.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Maryland-College Park(UMCP)	Supporting Organization	Academia	College Park, Maryland

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

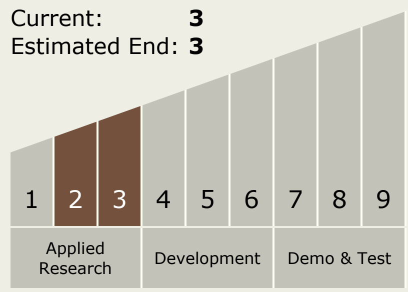
Raymond Sedwick

Co-Investigator:

John J Vitucci

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX01 Propulsion Systems
  └ TX01.2 Electric Space Propulsion
    └ TX01.2.3 Electromagnetic

Primary U.S. Work Locations
Maryland

Images

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Project Image Development of a Superconducting Helicon Thruster
(https://techport.nasa.gov/image/1747)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html